U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-255 107

THE STATUS AND QUALITY OF RADIATION MEASUREMENTS OF WATER

ENVIRONMENTAL MONITORING AND SUPPORT LABORATORY

APRIL 1976

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/4-76-017	2.
3. RECIPIENT'S ACCESSION NO. PB255107	
4. TITLE AND SUBTITLE THE STATUS AND QUALITY OF RADIATION MEASUREMENTS OF WATER	5. REPORT DATE April 1976 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) A. N. Jarvis, R. F. Smiecinski, D. G. Easterly	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Environmental Monitoring and Support Laboratory Office of Research and Development U.S. Environmental Protection Agency Las Vegas, Nevada 89114	10. PROGRAM ELEMENT NO. 1HD621 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Same as above	13. TYPE OF REPORT AND PERIOD COVERED Interim, 1974 14. SPONSORING AGENCY CODE EPA-ORD-Office of Monitoring and Technical Support
15. SUPPLEMENTARY NOTES	

16. ABSTRACT

As part of the radiation quality assurance program conducted by the U.S. Environmental Protection Agency, calibrated radionuclide solutions are distributed to participating laboratories for instrument calibration and yield determinations. Laboratory performance studies involving the analysis of radionuclides in environmental media are also conducted.

A summary is given of the results of the water cross-check program for 1974. Examination of these results reveals that gross beta is the most difficult (44 percent within the control limits) and tritium is the least difficult (90 percent within the control limits) for the laboratories to analyze. These results indicate the need for improvement in analytical procedures for the radionuclide studies.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
radiation chemistry	chromium-51	laboratory performance	07E
quality assurance	cobalt-60	intercomparison studies	12B
quality control	zinc-65	cross-check	14D
water analysis	ruthenium-106	gross alpha	18B,D,H
isotopes	cesium-134	gross beta	
radium-226	cesium-137		
tritium			

18. DISTRIBUTION STATEMENT RELEASE TO PUBLIC	19. SECURITY CLASS *(This Report)* UNCLASSIFIED	21. NO. OF PAGES 30
	20. SECURITY CLASS *(This page)* UNCLASSIFIED	22. PRICE 4 00

EPA Form 2220-1 (9-73)

☆GPO 691-219-1976

209118

PB 255 107

EPA-600/4-76-017
April 1976

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EPA-600/4-76-017
April 1976

THE STATUS AND QUALITY OF RADIATION MEASUREMENTS OF WATER

by

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INTRODUCTION

Environmental radiation measurements are made daily by Federal, State, local, and private agencies. The data obtained from these measurements are utilized by the U.S. Environmental Protection Agency (EPA) and other agencies for such purposes as estimating dose, health effects, establishing standards and guides, and conducting regulatory activities. It is therefore imperative that the precision and accuracy of the data be assured so that policy decisions concerning environmental quality are based on valid and comparable data.

The present radiation quality assurance program of the EPA is designed to encourage the development and implementation of quality control procedures at all levels of sample collection, analysis, data processing, and reporting. As an integral part of the EPA's program, the Quality Assurance Branch of the Environmental Monitoring and Support Laboratory-Las Vegas (EMSL-LV) distributes calibrated radionuclide solutions for instrument calibration and chemical yield determinations, and conducts a number of laboratory performance studies involving the analysis of radionuclides in environmental media.

The intercomparison studies program enables participating laboratories to maintain checks on their analyses and assists them in documenting the validity of their data. In addition, this program enables the EPA to obtain an overall estimate of the precision and accuracy of environmental radiation measurements, or more precisely the precision and accuracy of laboratory radioassay procedures for environmental samples.

Studies currently in progress involve samples of most environmental media and include milk, air, water, soil, diet, urine, and noble gases. Table 1 is a summary of the cross-check programs. Participants include nuclear facilities and/or their contractors, and State, Federal, and international laboratories. The number of participants has increased steadily during the past two years. Because of the large number of participants and the continuing nature of the programs, sufficient data are generated to enable periodic assessment of the quality of environmental data.

Participating laboratories perform analyses on the cross-check samples and return their data to the Quality Assurance Branch for statistical analysis. Comparisons are made between laboratories and within an individual laboratory for accuracy and precision. A computer report and a periodically updated performance chart are returned to each participant. This enables each laboratory to document the precision and accuracy of its radiation data, to identify instrumental and procedural problems, and to compare performance with other laboratories.

Reported herein are the results of that portion of the quality assurance studies which concerns the measurements of radionuclides in water samples.

TABLE 1. SUMMARY OF CROSS-CHECK PROGRAMS*

SAMPLE	ANALYSIS	ACTIVITY PER ISOTOPE	QUANTITY SUPPLIED	PRESERVATIVE	DISTRIBUTION	TIME FOR ANALYSIS & REPORT
Milk	^{89}Sr, ^{90}Sr, ^{131}I, ^{137}Cs, ^{140}Ba, K	< 200 pCi/l	~ 4 liters	Formalin	Bimonthly	6 weeks
Water						
Gross α, β*	Gross α, β	< 100 pCi/l	~ 4 liters	0.5N HNO_3	Bimonthly	4 weeks
Gamma	^{60}Co, ^{106}Ru, ^{134}Cs, ^{137}Cs, ^{51}Cr, ^{65}Zn	< 500 pCi/l	~ 4 liters	0.5N HNO_3	Bimonthly	4 weeks
^{3}H	^{3}H	< 3500 pCi/l	~ 60 ml	none	Bimonthly	4 weeks
^{239}Pu*	^{239}Pu	< 10 pCi/l	~ 4 liters	0.5N HNO_3	Semiannually	8 weeks
^{226}Ra	^{226}Ra	< 20 pCi/l	~ 4 liters	0.5N HNO_3	Quarterly	6 weeks
Air						
Gross α, β*	α, β, γ	< 200 pCi/sample	3 - 2" or 4" diam. air filters	none	Quarterly	4 weeks
^{239}Pu*	^{239}Pu	< 2 pCi/sample	3 - 2" or 4" diam. air filters	none	Quarterly	6 weeks
Soil*	^{239}Pu	< 50 pCi/sample	~ 100 g	none	Semiannually	8 weeks
Diet	^{89}Sr, ^{90}Sr, ^{131}I, ^{137}Cs, ^{140}Ba, K	< 200 pCi/kg	3 - 4-liter samples	Formalin	Quarterly	8 weeks
Urine	^{3}H	< 3500 pCi/l	~ 60 ml	Formalin	Quarterly	4 weeks
Gas	^{85}Kr	< 20 pCi/ml	10 liters	none	Semiannually	8 weeks

* Laboratories are required to have the necessary licenses before receiving these samples.

METHODS AND PROCEDURES

Water samples containing known amounts of specific radionuclides are prepared and distributed to a number of Federal, State, and private laboratories. These samples are designed to test the ability of participating laboratories to analyze water for gross alpha and gross beta activity, radium-226, gamma-emitting isotopes, and tritium. A schedule of the water samples distributed during 1974 is shown below.

Analysis	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Gross Alpha Activity		x		x			x		x		x	
Gross Beta Activity		x		x			x		x		x	
Radium-226	x				x		x					
Gamma Emitters	x		x		x			x		x		x
Tritium	x		x		x			x		x		x

The quantity and activity levels of each type of sample are described in the following paragraphs.

1. Samples for the Analysis of Gross Alpha and Gross Beta Activity

A 4-liter water sample containing known amounts of americium-241 and strontium-90-yttrium-90 was sent to each participant. Five different samples were distributed during 1974. The concentration of americium-241 varied from 50 pCi/liter (November) to 90 pCi/liter (April), while that of strontium-90-yttrium-90 varied from 24 pCi/liter (February) to 190 pCi/liter (April).

2. Samples for the Analysis of Radium-226

A 4-liter water sample containing known amounts of radium-226 was distributed to each participating laboratory. During 1974 four different samples were supplied for analysis. The concentrations of radium-226 in these samples varied from 5 pCi/liter (July and November) to 16 pCi/liter (January).

3. Samples for Gamma-Emitting Isotopes

Four-liter water samples containing different gamma-emitting isotopes were supplied to each participant. In this study an attempt was made to identify instrumental or calibration problems that might exist in the participating laboratories. Therefore, from January 1974 through October 1974 known amounts of a single radionuclide were added to the water. Each of the five intercomparison studies conducted during this period contained a different radionuclide, i.e., zinc-65, cobalt-60, chromium-51, ruthenium-106, and cesium-134. The concentrations varied from 339 pCi/liter (chromium-51

in May) to 481 pCi/liter (cesium-134 in October). In December 1974, the samples contained a mixture of cesium-134 (452 pCi/liter), cesium-137 (497 pCi/liter), and cobalt-60 (478 pCi/liter).

4. Samples for Tritium Analysis

During 1974, 60-milliliter samples containing known amounts of tritium were supplied to participating laboratories on a bimonthly basis. The concentrations of these samples varied from 1491 pCi/liter (August) to 3395 pCi/liter (March).

PREPARATION OF WATER SAMPLES

1. The water utilized in preparing samples for gross alpha and gross beta activity analyses, radium-226 measurements, and for the assay of gamma-emitting radionuclides, is a mixture of distilled water, aged for a minimum of 30 days, tap water, and nitric acid. This mixture is prepared in large 100-gallon plastic tanks. Appropriate amounts of the three constituents are added to the tank and stirred for 3 hours. Upon completion of the initial mixing, aliquots are removed and counted for background determination before the radionuclides are added. Prior to the addition of the "spike," the water sample consists of 0.5N nitric acid and 10 percent tap water, and contains 70 to 75 milligrams/liter of dissolved and suspended solids. Accurately measured amounts of the desired radionuclides are added to the water and stirred constantly for approximately 17 hours. The solution is then transferred to 4-liter cubitainers for distribution to participants. However, three aliquots are analyzed for activity and the homogeneity of the total sample checked before the individual samples are shipped to the participating laboratories.

2. Deep-well water containing no more than 15 pCi/liter of tritium is utilized in the preparation of the tritium samples. The well water is distilled and checked for the presence of chloride ions. The total water sample is then divided. Half of the distillate is utilized in the preparation of 60-milliliter background samples, while the desired amount of the tritium is added to the other half. The portion containing the tritium is thoroughly mixed and sealed in 60-milliliter glass bottles for distribution. Before shipping to participants, random samples are analyzed and the batch checked for homogeneity.

ANALYSIS BY PARTICIPANTS

Participating laboratories conduct three independent determinations for each radionuclide included in the particular cross-check sample and report the results to the Quality Assurance Branch. Control limits (sigma limits) previously established by the Analytical Quality Control Service in Winchester, Massachusetts, are used in analyzing the quality of the results obtained by these laboratories. These limits are based on the purpose for which the data are being obtained and on reasonable laboratory ability. Upon receipt of the reports from all participating laboratories, the data are analyzed using a computer. This analysis includes determination of the experimental average and standard deviation (S) of the samples, the normalized range ($\bar{R}$), standard error, normalized deviation, experimental sigma, and the grand average of all laboratories for each radionuclide. Examples of sample calculations to illustrate the computations performed by the computer are shown in the Appendix.

A report is generated containing the data reported by all participating laboratories, listed according to identity code, along with the results of the data analysis. Examples are shown in Figure 1. In addition, a control chart is generated for each radionuclide included in the sample (Figure 2). The control charts are updated each time a laboratory participates in a cross-check study, thus giving each laboratory a continuous record of its performance. A copy of the computer printout and a control chart for each radionuclide are mailed to each participant approximately 4 weeks following the report due date.

EMSL-LV TRITIUM IN WATER CROSS-CHECK PROGRAM - - - DECEMBER 1974

12/27/74 SAMPLE - A 3H

KNOWN VALUE = 1579 PCI/L
EXPECTED LABORATORY PRECISION (1S, 1 DETERMINATION) = 332 PCI/L

LAB	RESULT	EXPERIMENTAL SIGMA	RNG ANLY ($\bar{R}$ = SR)	AVERAGE	NORMALIZED DEVIATION (GRAND AVG)	(KNOWN)
D	1500					
D	1400					
D	1400	57.7	.18	1433	-1.5	-.8
P	1872					
P	1688					
P	1596	140.5	.49	1719	-.0	.7
AG	1830					
AG	1810					
AG	1740	47.3	.16	1793	.4	1.1
AH	1626					
AH	1477					
AH	1652	94.4	.31	1585	-.7	-.0
AI	2011					
AI	1713					
AI	2473	382.9	1.41	2066	1.8	2.5
E	NO DATA PROVIDED					

EXPERIMENTAL SIGMA (ALL LABS) = 272 GRAND AVERAGE = 1719

Figure 1. Sample analysis and report of participant's data

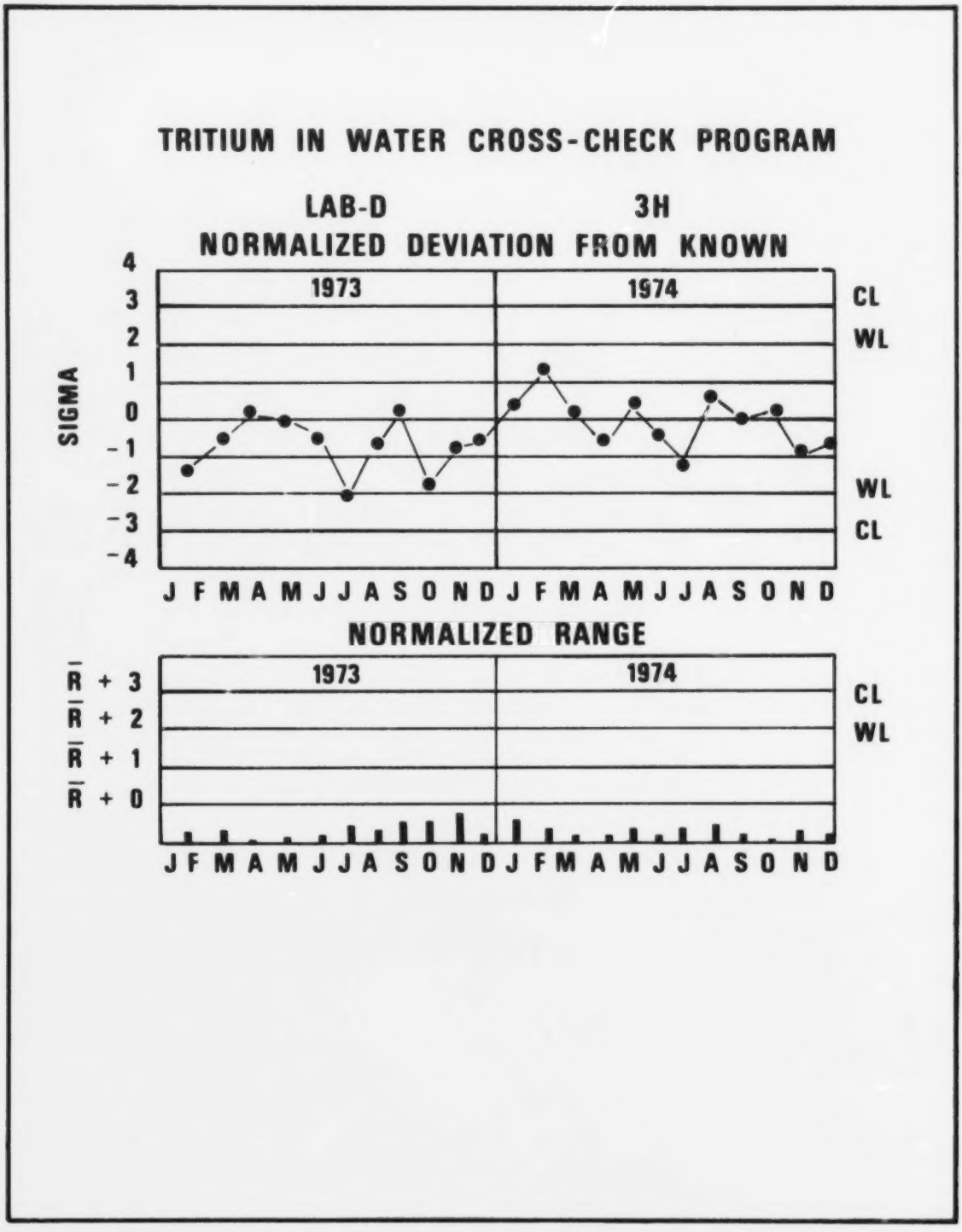

Figure 2. Control chart

RESULTS AND DISCUSSION

1. Gross Alpha Activity

The results of the gross alpha studies are summarized in Table 2 and Figure 3. Most of the reported results are within the established control limits. The internal precision of the individual laboratories, although not shown in this paper, appears to be generally satisfactory. However, there is a need for improved accuracy, as indicated by the difference between the average and known values. Moreover, in the five studies, the average of the reported results ($\bar{x}$) in all cases, was less than the known amounts of activity added to the sample (μ). This negative bias may be due to the loss of a portion of the sample, resulting from adherence to the sides of the beaker during the evaporative procedure employed in sample preparation.

The values (σ/μ) times 100 and (s/μ) times 100 obtained from the five studies are compared in Table 2. These values indicate that the control limits are realistic and, with improved calibration procedures and uniform methodology, readily attainable.

2. Gross Beta Activity

The results of the gross beta studies are illustrated in Figure 4 and summarized in Table 2. In all five of these studies the average values reported by the participants exceeded the known values. This positive bias may be due to the fact that commonly used procedures require that gross beta values be corrected for gross alpha interference. Since the gross alpha values are consistently low, as indicated above, the alpha correction factors applied may not be large enough.

The intralaboratory precision for gross beta analysis appears to be quite satisfactory. However, the accuracy of these measurements is unsatisfactory. A significant number of the values reported by the participating laboratories extend beyond the control limits, indicating that the expected accuracy of the gross beta analytical procedure is not being attained. Comparison of (σ/μ) times 100 with the experimentally determined (s/μ) times 100 further indicates that a large number of participating laboratories are not meeting the established limits.

TABLE 2. SUMMARY OF WATER ANALYSIS DATA FOR GROSS ALPHA AND GROSS BETA ACTIVITY, 1974

	February	April	July	September	November
			ALPHA		
μ (pCi/liter)	51	95	75	25	50
σ limit (pCi/liter)	13	24	19	6.3	12.6
$(\sigma/\mu) \times 100$ (%)	25.5	25.3	25.3	25.2	25.2
N	28	27	28	30	31
$\bar{x}$ (pCi/liter)	38	64	59	21	41
s (pCi/liter)	19	28	26	8	15
$(s/\mu) \times 100$ (%)	37.3	29.5	34.7	32.0	30.0
			BETA		
μ (pCi/liter)	24	190	103	77	51
σ limit (pCi/liter)	5	10	5	5.0	5.0
$(\sigma/\mu) \times 100$ (%)	20.8	5.3	4.9	6.5	9.8
N	30	30	30	30	34
$\bar{x}$ (pCi/liter)	33	199	112	80	57
s (pCi/liter)	9	39	21	15	13
$(s/\mu) \times 100$ (%)	37.5	20.5	20.4	19.5	25.5

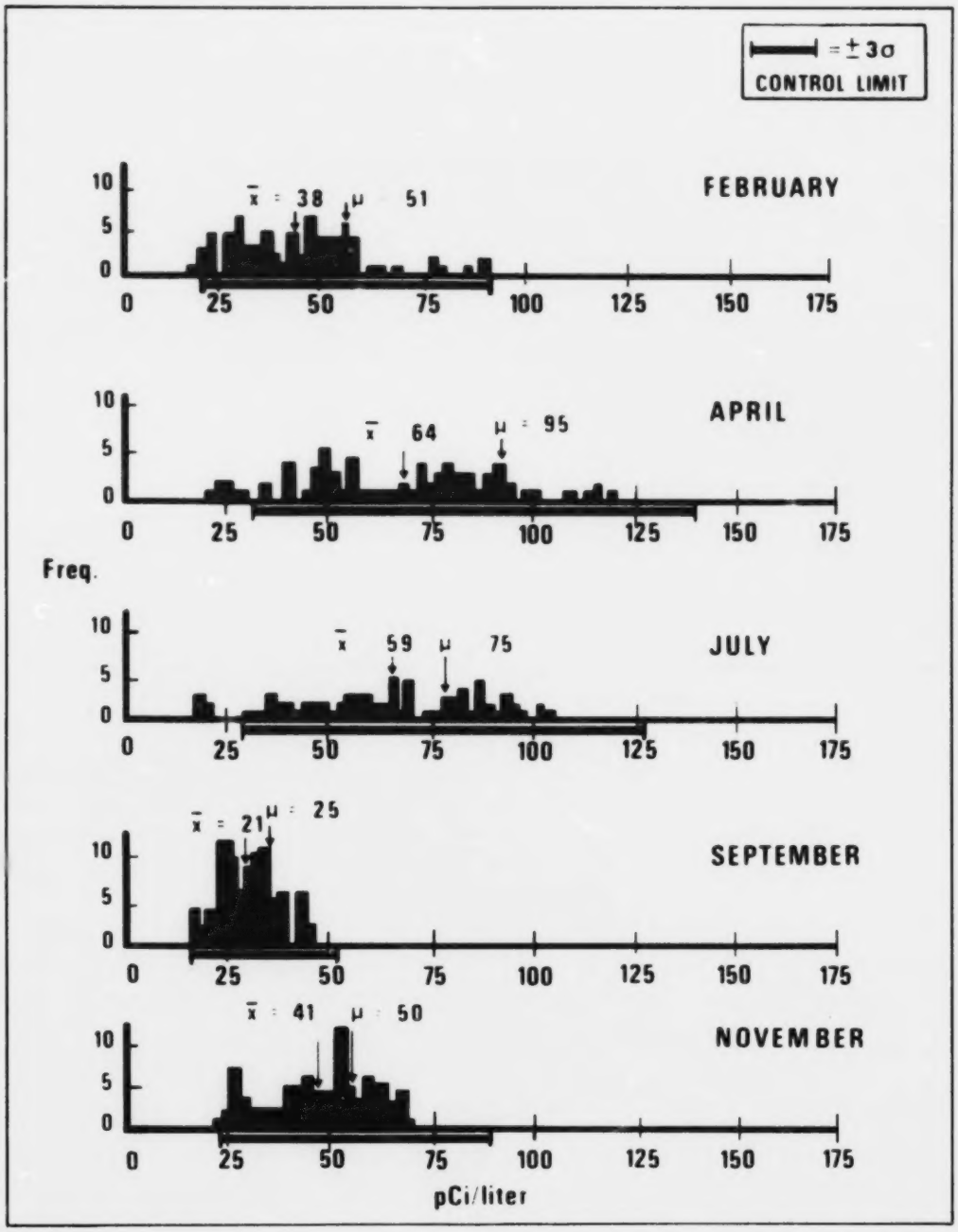

Figure 3. Histogram of gross alpha activity in water results, 1974

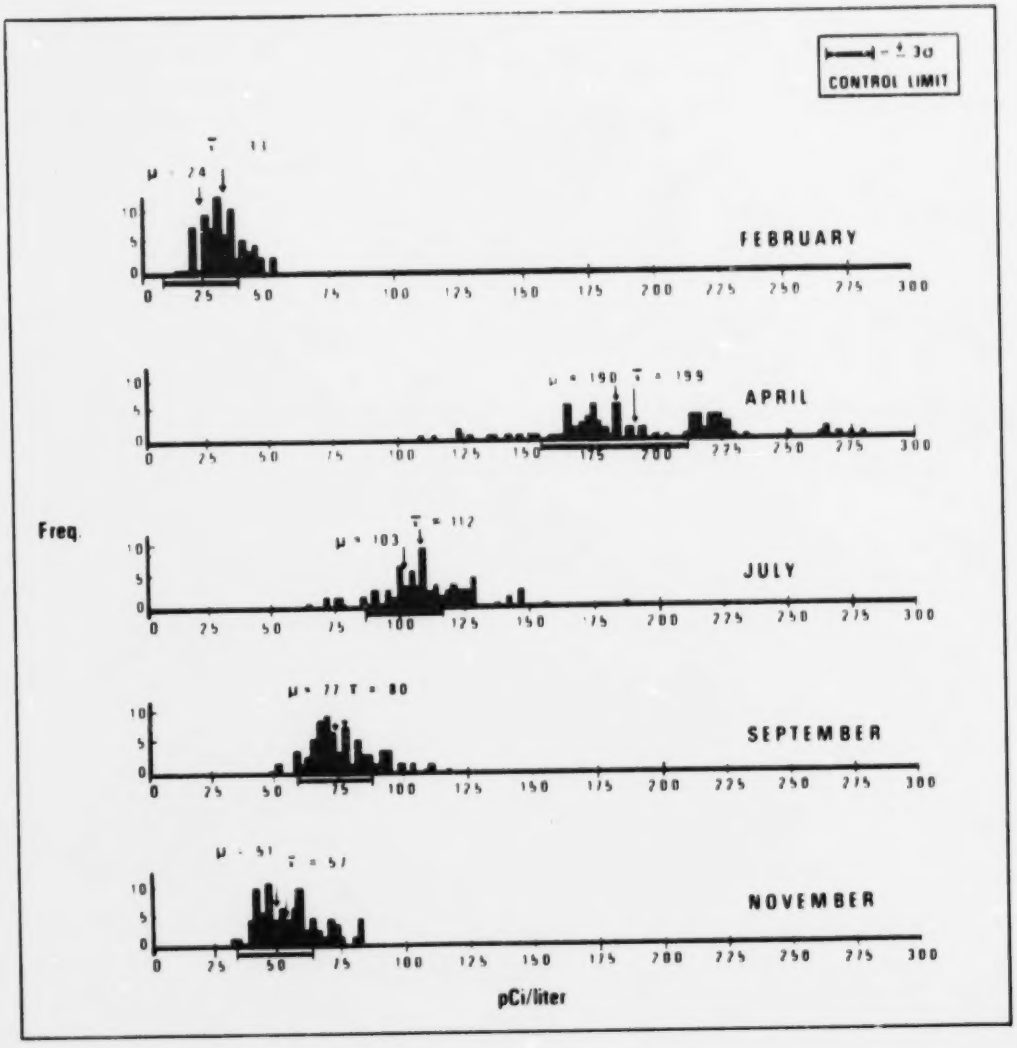

Figure 4. Histogram of gross beta activity in water results, 1974

3. Radium-226

The results of the radium-226 studies are shown in Figure 5 and Table 3. These results indicate most of the participating laboratories are performing satisfactory analysis. Eighty percent of the reported values are within the established control limits. Although not shown in this report, the internal precision of the individual laboratories appears to be satisfactory. Comparison of (σ/μ) times 100 with the experimentally determined (s/μ) times 100 indicates most participating laboratories are meeting the established limits.

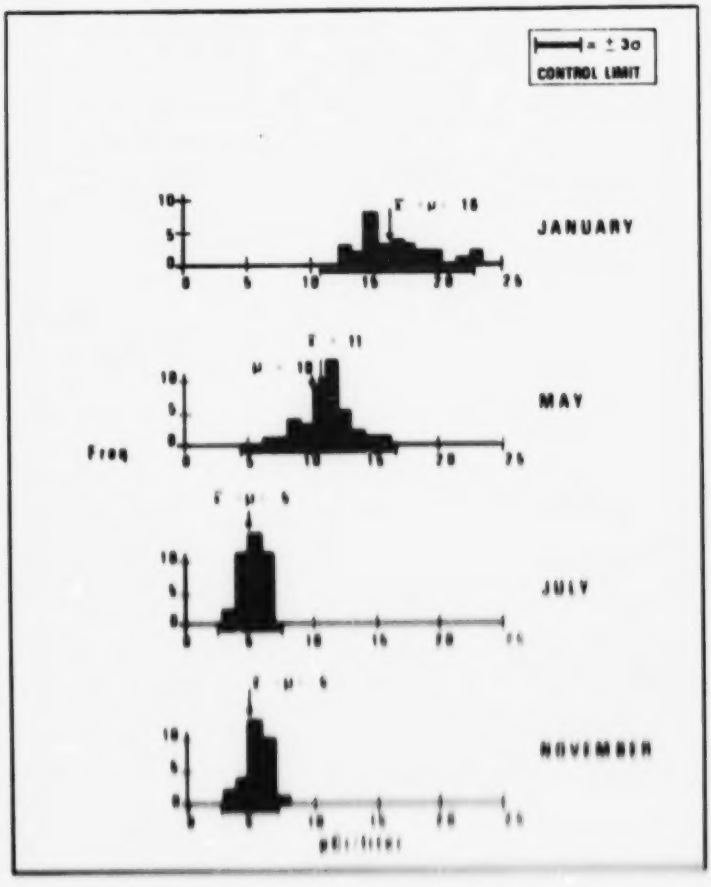

Figure 5. Histogram of radium-226 in water results, 1974

TABLE 3. SUMMARY OF WATER ANALYSIS DATA FOR RADIUM-226, 1974

	January	May	July	November
μ (pCi/liter)	16	10	5.1	4.9
σ limit (pCi/liter)	2	2	0.8	0.7
$(\sigma/\mu) \times 100$ (%)	12.5	20.0	15.7	14.3
N	10	14	13	10
$\bar{x}$ (pCi/liter)	16	11	5	5
s (pCi/liter)	3	2	1	1
$(s/\mu) \times 100$ (%)	18.8	20.0	19.6	20.4

4. Tritium

The results of the tritium studies are shown in Table 4 and Figure 6. The established control limits for tritium are a function of the concentration as shown in Figure 7. For the analyses of the six intercomparison studies, the range of these limits varies from 10.2 to 23.0 percent of the known value at the 1 sigma control limit. Of all the water analyses performed by the cross-check participants, the tritium results indicate that 90 percent of the laboratories are within the 3 sigma control limits. Also, the results show no significant bias.

One reason for these results may be attributed to the fact that all laboratories use essentially the same method of analysis. Again, the precision (not shown) for tritium analysis appears good. A comparison of (σ/μ) times 100 with the experimentally determined (s/μ) times 100 further substantiates the accuracy of the data reported by the participating laboratories.

TABLE 4. SUMMARY OF WATER ANALYSIS DATA FOR TRITIUM, 1974

	January	March	May	August	October	December
μ (pCi/liter)	1755	3395	2673	1438	1975	3395
σ limit (pCi/liter)	335	346	353	331	350	356
$(\sigma/\mu) \times 100$ (%)	19.1	10.2	13.2	23.0	17.7	10.5
N	38	41	40	33	37	44
$\bar{x}$ (pCi/liter)	1771	3331	2669	1491	1979	3252
s (pCi/liter)	324	332	236	255	301	307
$(s/\mu) \times 100$ (%)	18.5	9.8	8.8	17.7	15.2	9.0

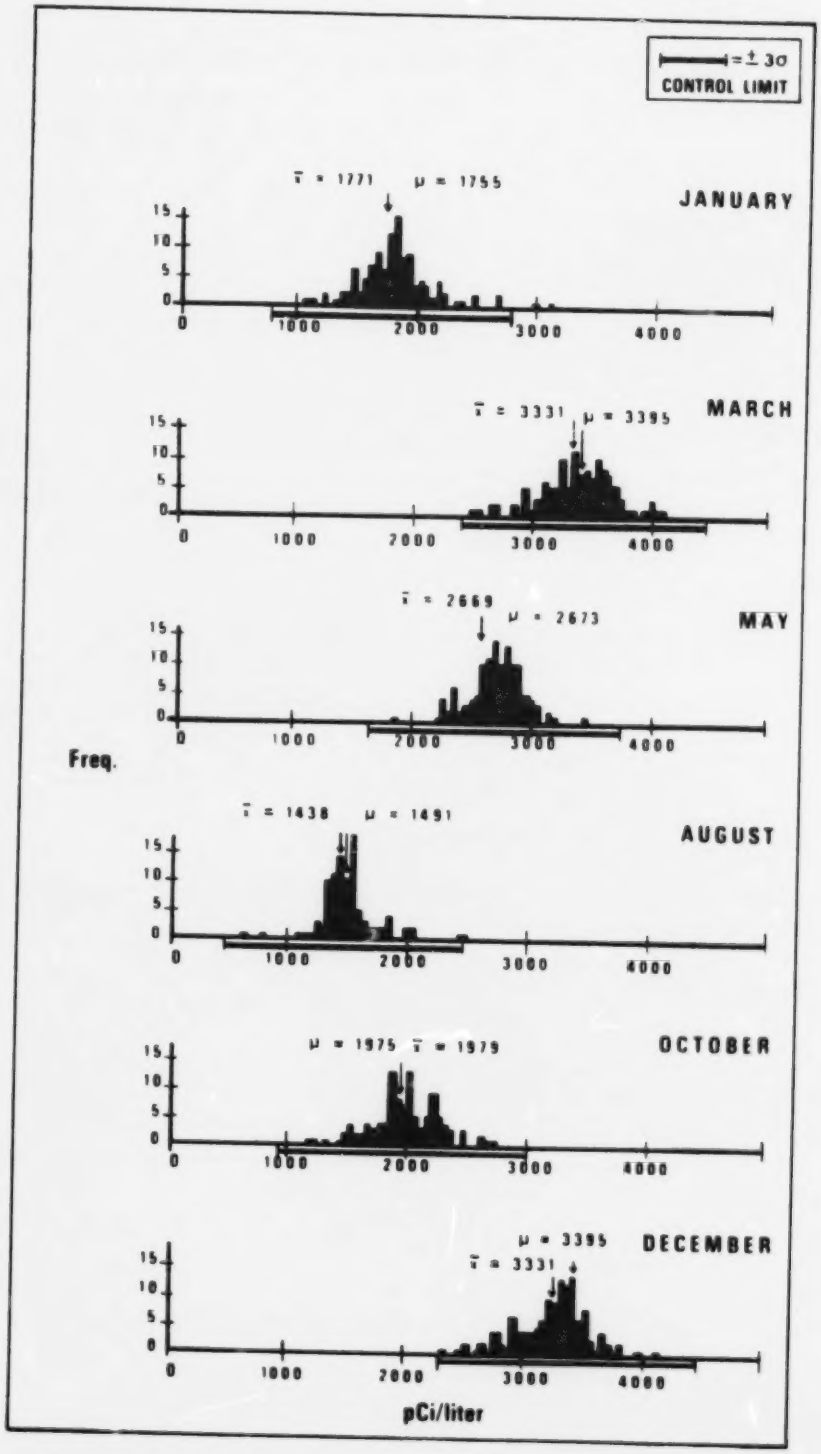

Figure 6. Histogram of tritium in water results, 1974

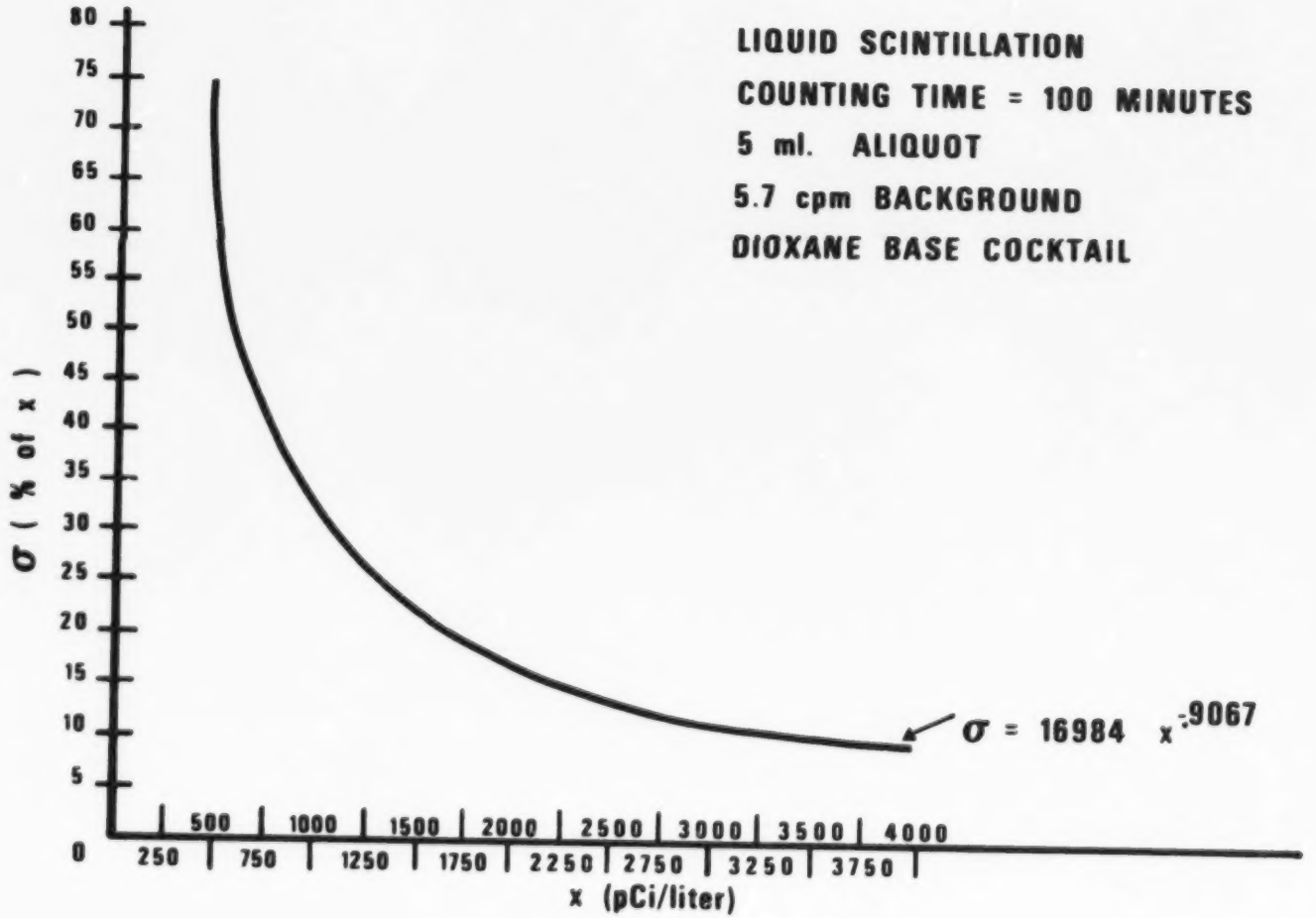

Figure 7. Standard deviation as a function of tritium concentration

5. Gamma

The results of the gamma in water studies are summarized in Table 5 and Figure 8. All cross-check samples contained single nuclides with the exception of the December sample which contained cesium-134, cesium-137, and cobalt-60. Ability of the participating laboratories to perform gamma analyses varied markedly with individual nuclides. Of the participating laboratories, 77 percent were within the 3 sigma control limits for cobalt-60 while only 50 percent were within the limits for chromium-51. Since ruthenium-106, chromium-51, zinc-65, and cesium-137 were present in only one cross-check sample each, and cobalt-60 and cesium-134 present in only two, no definite conclusion with regard to laboratory performance can be made at this time. However, results of the samples containing only one gamma-emitting radionuclide would suggest a need for better instrument calibration procedures.

TABLE 5. SUMMARY OF WATER ANALYSIS DATA FOR GAMMA, 1974

	January	March	May	August	October	--- December ---		
	^{65}Zn	^{60}Co	^{51}Cr	^{106}Ru	^{134}Cs	^{60}Co	^{134}Cs	^{137}Cs
μ (pCi/liter)	372	490	349	421	481	478	452	497
σ limit (pCi/liter)	19	24	17	21	24	24	23	25
$(\sigma/\mu) \times 100$ (%)	5.1	4.9	5	5	5	5	5	5
N	31	29	30	34	39	31	34	32
$\bar{x}$ (pCi/liter)	392	478	331	423	467	476	440	496
s (pCi/liter)	52	29	53	49	40	23	39	41
$(s/\mu) \times 100$ (%)	14.0	5.9	15.2	11.6	8.3	4.8	8.6	8.3

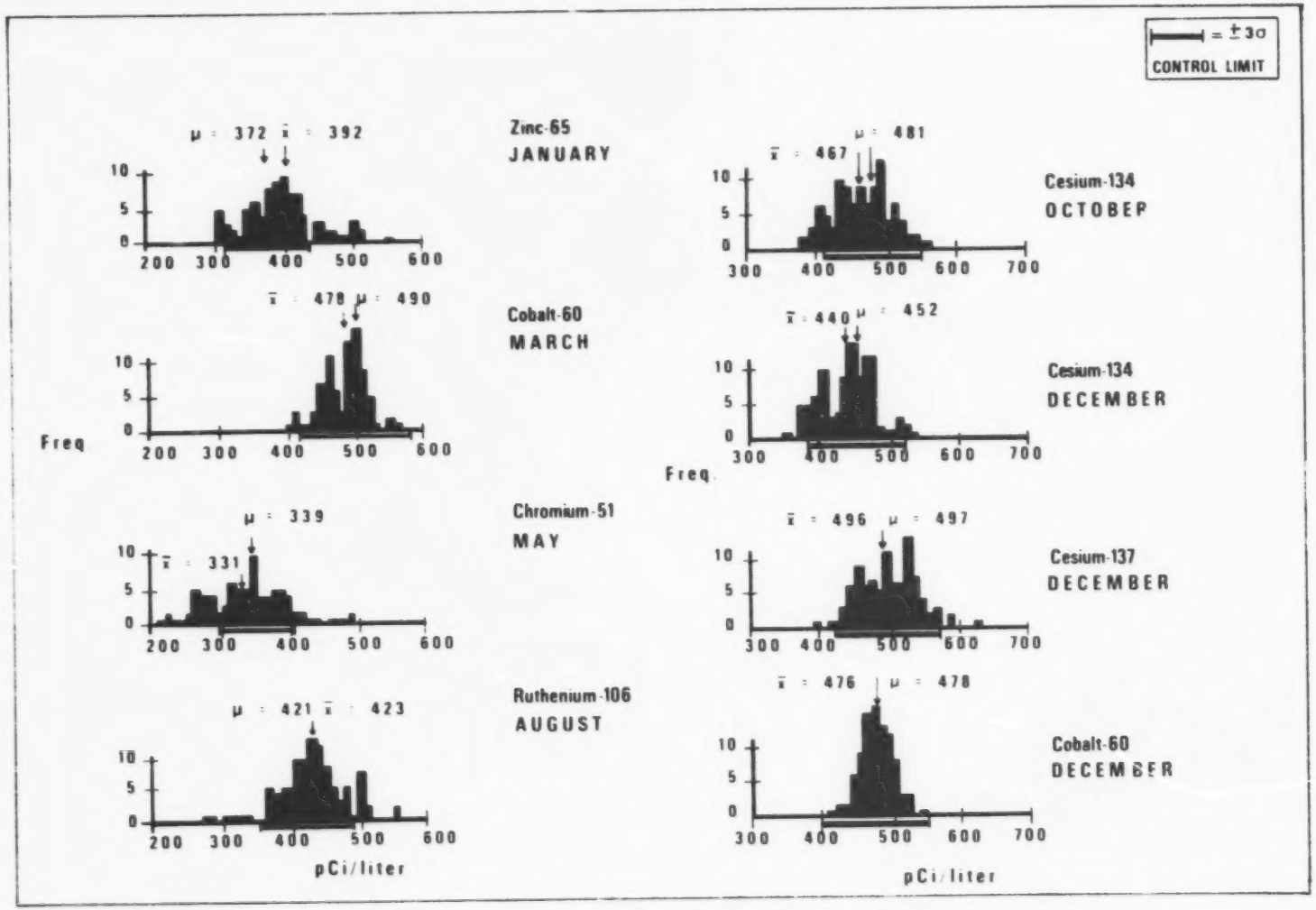

Figure 8. Histogram of gamma in water results, 1974

Table 6 is a summary of the results for the ten analyses performed on the water cross-check samples by the participating laboratories. Using the percentage of laboratories reporting data within the 3 sigma control limits as criteria, the nuclides are listed in order of the ability of the laboratories to perform the radionuclide analysis.

TABLE 6. SUMMARY OF LABORATORY PERFORMANCE
1974 INTERLABORATORY COMPARISON STUDIES - WATER

Radionuclide Analysis	% of Laboratories Within ± 3 (99.7% Control Limits)
Tritium	90
Radium-226	80
Cobalt-60	77
Gross Alpha	67
Ruthenium-106	63
Cesium-134	62
Cesium-137	62
Zinc-65	55
Chromium-51	50
Gross Beta	44

The conclusions drawn from these data, of necessity, have been very general due to the limited amount of available data. The data indicate tritium to be the least difficult (90 percent within the control limits), and gross beta to be the most difficult (44 percent within the control limits) for laboratories to analyze. Sufficient data must be compiled over a longer period of time to obtain a valid idea of laboratory performance. When sufficient data are compiled, such parameters as control limits, methods of analysis, and instrument calibration must be critically assessed in determining laboratory performance and, if necessary, how improvement can best be achieved.

APPENDIX. STATISTICAL CALCULATIONS

To illustrate the computations performed by the computer, example calculations are given using data for three actual samples analyzed at one laboratory (Laboratory D).

The experimental data are listed and the mean, range, and the experimental sigma are computed. These statistics provide measures of the central tendency and dispersion of the data.

The normalized range is computed by first finding the mean range, $\bar{R}$, the control limit, CL, and the standard error of the range, σ_R. The normalized range measures the dispersion of the data (precision) in such a form that control charts may be used. Control charts allow one to readily compare past analytical performance with present performance. In the example, the normalized range equals 0.3 $\bar{R}$ which falls inside the upper warning level, $\bar{R} + 2\sigma_R$. The precision of the results is acceptable.

The normalized deviation is calculated by computing the deviation and the standard error of the mean, σ_m. The normalized deviation allows one to readily measure central tendency (accuracy) through the use of control charts. Trends in analytical accuracy can be determined in this manner. For this example, the normalized deviation is -0.7 which falls within the upper and lower warning levels. The accuracy of the data is acceptable.

Finally, the experimental error of all laboratories, the grand average, and the normalized deviation from the grand average are calculated in order to ascertain the performance of all the laboratories as a group. Any bias in methodology or instrumentation may be found from these results.

EXAMPLE CALCULATIONS (Laboratory D Data)

Experimental data:

Known value = μ = 3273 pCi ^{3}H/liter urine on September 24, 1974

Expected laboratory precision = σ = 357 pCi/liter

Laboratory	Sample	Result
D	x_1	3060 pCi/liter
D	x_2	3060 pCi/liter
D	x_3	3240 pCi/liter

Mean = $\bar{x}$

$$\bar{x} = \frac{\sum_{i=1}^{N} x_i}{N} = \frac{9360}{3} = 3120 \text{ pCi/liter}$$

where N = number of results

Range = r

$$r = |\text{maximum result} - \text{minimum result}|$$

$$= |3240 - 3060| = 180 \text{ pCi/liter}$$

Experimental sigma = s

$$s = \sqrt{\frac{\sum_{i=1}^{N} (x_i)^2 - \frac{\left(\sum_{i=1}^{N} x_i\right)^2}{N}}{N - 1}}$$

$$= \sqrt{\frac{(3060)^2 + (3060)^2 + (3240)^2 - \frac{(3060 + 3060 + 3240)^2}{3}}{2}}$$

$$= 103.9 \text{ pCi/liter}$$

Normalized range = $w\bar{R} + x\sigma_R$

Mean range = $\bar{R}$

$$\bar{R} = d_2\sigma \qquad \text{where } d_2 = 1.693 \text{ for } N = 3^*$$
$$= (1.693)(357)$$
$$= 604.4 \text{ pCi/liter}$$

Control limit = CL

$$CL = \bar{R} + 3\sigma_R$$
$$= D_4\bar{R} \qquad \text{where } D_4 = 2.575 \text{ for } N = 3^*$$
$$= (2.575)(604.4)$$
$$= 1556 \text{ pCi/liter}$$

Standard error of the range = σ_R

$$\sigma_R = 1/3\ (\bar{R} + 3\sigma_R - \bar{R})$$
$$= 1/3\ (D_4\bar{R} - \bar{R})$$
$$= 1/3\ (1556 - 604.4)$$
$$= 317.2 \text{ pCi/liter}$$

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* Rosenstein, M., and A. S. Goldin, *Statistical Techniques for Quality Control of Environmental Radioassay*, AQCS Report Stat-1, U.S. Department of Health, Education and Welfare, PHS, Nov 1964

$$w\bar{R} + x\sigma_R = 1\bar{R} + x\sigma_R$$

$$= 1\bar{R} + \left[\frac{r - w\bar{R}}{\sigma_R}\right]\sigma_R \qquad \text{for } r > \bar{R}$$

$$w\bar{R} + x\sigma_R = w\bar{R} + o\sigma_R$$

$$= w\bar{R}$$

$$= \left[\frac{r}{\bar{R}}\right]\bar{R} \qquad \text{for } r \leq \bar{R}$$

$$= \left[\frac{180}{604.4}\right]\bar{R} \qquad \text{since } 180 < 604.4$$

$$= 0.30\ \bar{R}$$

Normalized deviation of the mean from the known value = ND

Deviation of mean from the known value = D

$$D = \bar{x} - \mu$$

$$= 3120 - 3273$$

$$= -153 \text{ pCi/liter}$$

Standard error of the mean = σ_m

$$\sigma_m = \frac{\sigma}{\sqrt{N}}$$

$$= \frac{357}{\sqrt{3}}$$

$$= 206.1 \text{ pCi/liter}$$

$$ND = \frac{D}{\sigma_m}$$

$$= \frac{-153}{206.1}$$

$$= -0.7$$

Experimental sigma (all laboratories) = s_t

$$s_t = \sqrt{\frac{\sum_{i=1}^{N} (x_i)^2 - \frac{\left(\sum_{i=1}^{N} x_i\right)^2}{N}}{N - 1}}$$

$$= \sqrt{\frac{162639133 - \frac{(49345)^2}{15}}{14}}$$

$$= 149 \text{ pCi/liter}$$

Grand average = GA

$$= \frac{\sum_{i=1}^{N} x_i}{N}$$

$$= \frac{49345}{15}$$

$$= 3290 \text{ pCi/liter}$$

Normalized deviation from the grand average = ND'

Deviation of the mean from the grand average = D'

$$D' = \bar{x} - GA$$

$$= 3120 - 3290$$

$$= - 170 \text{ pCi/liter}$$

$$ND' = \frac{D'}{\sigma_m}$$

$$= \frac{- 170}{206.1}$$

$$= - 0.8$$